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Biosphere, Markets and Governments

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Introduction

Human economic activities are forcing changes in the biosphere, the thin habitable layer at the surface of the planet and just above it.[2] This is where we live and die, the environment to which millions of years of evolution have adapted us. Significant changes in this environment can have far-reaching implications for human life and welfare. Human impacts on the biosphere at a global level are a new phenomenon. For most of history we have had local rather than global impacts on our planetary environment. In contrast over the last half-century we have begun to affect the operation the basic biogeochemical cycles that support life on earth: the carbon cycle, the hydrological cycle, the nitrogen cycle, and the composition of the web of species that accompany us. Because these impacts are new, we have not yet developed institutions that can mediate between human activities and the biosphere. In many cases the important aspects of the biosphere are common property resources: in some cases they are systems and commodities that are not even recognized as resources. Concrete examples are the need to mediate our impacts on the stratospheric ozone layer and on the carbon cycle. These will no doubt be followed by similar needs relating to the loss of biodiversity and to the planet's nitrogen cycle.

In the two cases in which we have taken action, or at least are taking action, we have chosen very different routes, the Montreal and Kyoto protocols. The former embodies the classic regulatory approach, dictating what can and cannot be done. The latter is centered much more about economic incentives generated by a market. It seeks to internalize externalities by creating and distributing property rights where none previously existed and then allowing these to be traded. The market here is central and is government-created. The same is true of the markets in the United States for SO_2 emissions.

[1] I am grateful to Todd Sandler for very insightful comments.
[2] See Vitousek et al., 1997 for details.

There is an alternative market-based approach that is less dependent on government activity – less dependent on but not independent of, for in this area (and arguably in all areas) markets depend on the government for their infrastructure of property rights and contract enforcement. This alternative approach involves privatizing and securitizing the biosphere. To be precise, it derives from the observation that the natural world provides many important services to human societies, termed by biologists ecosystem services.[3] These are fundamental to human life and comfort and are generally taken for granted. They include such services as climate stabilization, pollination, renewal of soil fertility, cleansing of water and control of floods, and control of pests.[4]

If the natural environment provides a range of important services to human societies, then might it not be possible to charge for the provision of these and in the process both provide incentives for their preservation and encourage efficient use? The idea would be to set up markets in environmental services, thus enlisting the price mechanism and the invisible hand in the goal of mediating human interactions with the biosphere. The distinguished biologist E.O. Wilson wrote once of the need to "give the invisible hand of market economics a green thumb". Characteristically he made the point well.

Prerequisites for this approach are of course property rights in the natural capital that supplies the ecosystem services. Such approaches are already working, and having a dramatic effect. The best example, to which I shall return, is the Conservation Corporation (ConsCorp) in South Africa. This is making profits by restoring degraded natural ecosystems from low-grade farmland and then using them for ecotourism and hunting. In the process they are both improving the lot of the local populations and conserving important elements of biodiversity. In effect they are selling ecosystem services. Many water companies are now doing the same: they are conserving the watersheds that provide them with drinkable water as a part of their business strategies. In selling water they are in effect selling the water collection and purification services of natural watersheds, which are frequently forests that support considerable biodiversity.

To summarize, there are two basic and quite distinct strategies for using markets to mediate human interactions with the natural environment. One is to establish markets for tradable permits in

[3] See Daily, 1997.

the use of common property resources, as is done with markets in pollution rights. One is here doing something that is at once natural to economists – establishing a market – and unnatural, as the goods concerned are public goods, and we teach our students that public goods are a classic example of market failure. The atmospheric concentration of CO_2 is a global public good: the concentration of SO_2 is a regional public good. Both are not just public goods: they are unusual public goods in that they are privately produced, produced by individual decisions about heating choices and transportation choices. So the use of markets to manage the provision of public goods that are privately provided is central to the strategies of the Kyoto Protocol and of the 1990 Clean Air Act of the United States, which is widely thought to have been successful at managing a reduction in sulfur dioxide emissions.

The other strategy for using markets is to use them to sell the services, ecosystem services, provided to human societies by natural assets. For this to be successful these services must be excludable and property rights must be established.

In both of these cases there is a central role for the government in augmenting the market. The roles are similar in the two cases, involving establishing property rights and establishing markets and the contractual frameworks that they need. In some cases this can happen in a decentralized fashion: privatization and securitization of ecosystem services has not to the best of my knowledge been on any government agenda, yet has occurred in important contexts. Its occurrence owes much to particular legal infrastructures already in place, that is, to prior government actions.

In the remainder of this paper I review each of these alternatives, beginning with the use of permit markets to control the provision of a privately-produced public good and moving on to an analysis of the potential for marketing the goods and services provided by natural ecosystems. Although both are relatively new developments, the former is the better established and better understood. We have a rather thorough understanding of what it can achieve and how it can operate. As we shall see, we know enough of the latter to realize that it has the potential to contribute a great deal, but still lack a comprehensive understanding of its potential for conservation of the natural environment.

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[4] Daily, 1997 provides a comprehensive list of ecosystem services and and analysis of how human societies depend on the natural environment.

Permit Markets and Public Goods

The use of tradable permit markets as a mechanism for controlling human interactions with the biosphere is growing and to date seems to have been successful. To understand the issues that this raises, I want to begin my discussion by focussing on an example. Carbon dioxide, the principal gas responsible for global climate change, is stable, remaining in the atmosphere for about 60 years after emission. It mixes well, and within months the carbon dioxide emitted in New York or Beijing will be diffused around the globe. The concentration of this gas in the atmosphere is thus rather uniform around the world, and the atmospheric concentration of carbon dioxide is a global public good.

How is all this CO_2 being produced? As a result of billions of decentralised and independent decisions by private households for heating or transportation, by corporations for these and other activities, all outside the government's sphere. The government can influence them—but only indirectly, through regulations or incentives. The same holds for other atmospheric pollutants. Sulphur dioxide is likewise produced by the home heating and power generation choices of people the world over. Ozone-depleting chlorofluorocarbons are produced for use in household refrigerators and air conditioners. The loss of biodiversity results from myriad independent decision about changes in land use, which destroy previous habitats, and from decisions about pollution, including those that affect the climate. Farmers, ranchers, vacation homeowners, suburban homeowners—all have a direct impact on biodiversity loss through their life styles and land use.

The foregoing observations introduce a completely new element into the provision of public goods. For traditional public goods, three questions are to be answered:

- How much should be provided?
- How should this be financed?
- How can the state obtain the information to answer these questions?

The last point relates of course to the famous free-rider problem. Anyone who is asked how much she or he is willing to pay for a public good—and who expects that their payment will be affected by the response—has an obvious incentive to give a response that understates the true preference. For privately produced public goods, however, we have to ask a fourth question:

- Given a desirable target level of production, how do we attain it, how is this target production to be divided between all of the potential producers?

For example, in the case of cutting back the emission of greenhouse gases this takes a very specific and difficult form: which countries should cut back emissions, and how much? The same question will then be repeated within the country, and indeed probably within organisations and firms. This new question—how the production of the public good should be distributed among agents—has surprising and interesting implications for the equity-efficiency dichotomy that has been traditional in welfare economics. In principle there are several ways of deciding how the production or abatement should be distributed between agents.

- One is the traditional command and control approach: take the total, divide it in some way among the possible producers, and instruct each of them that this is what they will produce. In the most common case of privately produced public goods—environmental pollution—this approach typically takes the form of deciding that there will be an X% reduction in the output of the pollutant and instructing everyone to reduce pollution by X%.
- The pollution can be reduced by taxation, trying to pick a tax rate that will bring about just the desired pollution level.
- A market can be used to decide who produces how much, by allocating pollution rights and allowing them to be traded.

Standard arguments indicate that either of the last two approaches—taxation or permit markets—is more cost-effective than command and control. Cost-effective here means that a given abatement level is achieved at a lower total cost. Of the two cost-effective approaches, markets are a better way of attaining a given target total pollution level, for the obvious reason that we can pick the total volume of pollution permits to equal the target pollution level. The idea of trading rights to pollute goes back at least to Dales (1968) and the 1970s, although it could be argued that it has origins in Coase (1960) or even in Lindahl's work on public goods (Foley 1970). For a general review of the issues, see Chichilnisky Heal and Starrett (1994) and Chichilnisky and Heal (1999)[5].

What issues does the use of markets raise in answering the “who produces” question for privately produced public goods? It is important to understand exactly how the market will work in this case. A total production level has been chosen for pollution, the total permissible pollution level. The next step is to allocate tradable rights to pollute—also known as tradable emission quotas—up to a total of the chosen total production target. These are divided among potential polluters according to a procedure chosen by the authority controlling the pollution.

To make this concrete, consider sulphur dioxide emission permits in the United States. The Environmental Protection Agency sets limits to the total emission of sulphur dioxide in a region, issues permits to emit SO_2 adding up to this limit, and then allocates these permits between potential polluters. Once this is done, the potential polluters are free to pollute up to the limit set by the permits that they have received. Alternatively they can pollute less and sell the permits for which they have no need, or they can purchase additional permits from other potential polluters and then pollute up to a level given by their initial allocation of permits plus their purchases. The incentive to cut back on pollution is provided by the fact that an unused permit can be sold, and an additional permit cost money: the higher the market price, the stronger the incentive.

How would this work for a global public good, such as CO_2? In other words, what are its implications for the Kyoto agreement on greenhouse gas emission? To introduce a regime of tradable emission quotas, we have to create property rights where none previously existed. These property rights must then be allocated to countries participating in the CO_2 abatement program, in the form of quotas. Such quotas have market value, perhaps very great market value. The creation and distribution of quotas could therefore lead to a major redistribution of wealth internationally. This means that it is economically and politically important to understand fully the issues that underlie an evaluation of alternative ways of distributing emission quotas. A clear precedent for this redistributive effect of international assignment of property rights can be seen in the Law of the Sea conference and the introduction of 200 mile territorial limits in the waters off a nation's coast. The limits established national property rights where none previously existed, and these rights

[5] Good general references are Tietenberg, 1980 and Atkinson, 1983.

could and frequently were distributed by governments to domestic firms. The creation of property rights in offshore water thus effected a very substantial redistribution of wealth internationally.

There is no way to restrict countries' emissions of greenhouse gases without altering their energy use—and without altering their overall production and consumption patterns. The implementation of measures to decrease carbon emissions will thus have a significant impact on the ability of different groups and countries to produce goods and services for their own consumption and for trade. Because of this, the distributional impact of environmental policy—the choice of who will bear the adjustment costs—is of major import. Under a tradable quota regime, payment for the provision of a public good—in this case payment for an atmosphere containing less greenhouse gases—takes the form of bearing the economic costs of adjusting to the quota regime and its prices. This makes the analysis of environmental policy particularly difficult because distributional considerations are typically the ones where consensus is most difficult to achieve.

Distribution and efficiency

Competitive market are intellectually attractive because of the efficiency of the allocations that result. Market efficiency requires three key properties:

- Markets must be competitive,
- There must be no external effects—in the Pigouvian terminology private and social costs must be equal, and in the Coasian there must be property rights in the environment,
- The goods produced and traded must be private.[6]

In this framework, the efficiency of market allocation is independent of the assignment of property rights. Ownership patterns are of great interest for welfare reasons, and different ownership patterns lead to different efficient allocations where traders achieve different levels of consumption and there are different distributions of income. But ownership patterns have no impact on market efficiency. The efficiency of the market independently of distribution is a crucial property underlying the organisation of most modern societies.

[6] We also require a complete set of markets for securities, present and future. This is a critical requirement in the context of managing risks by a market system.

Yet the efficiency properties that make the market so valuable for the allocation of private goods fail when the goods are public. With such goods it is not possible to separate efficiency from distribution. The public good nature of the atmospheric CO_2 has profound implications for the efficiency of market allocations, for efficiency and distribution are no longer divorced as they are in economies with private goods. Instead, they are closely associated. In economies with public goods, market solutions are efficient only with the appropriate distributions of initial property rights. As this is not a familiar result, let me state it formally and precisely.[7] Consider a world economy with I regions, $I>1$ indexed by $i=1,..,I$. Each region has a utility function u_i which depends on its consumption of a vector of private goods $c_i=(c_{i,1},c_{i,2},...,c_{i,M})$ where M is the number of private goods (indexed by m), and also on the quality of the world's atmosphere, a, which is a public good. Formally, $u_i(c_i,a)$ measures welfare, where u_i is a continuous, strictly concave and increasing function assumed to be twice continuously differentiable. The quality of the atmosphere a can be thought of as a measure of abatement. It could be measured by for example the reciprocal or the negative of the concentration of CO_2: the more abatement there is, the lower is this concentration. The concentration of CO_2 is "produced" by emissions of carbon, which are positively associated with the levels of production of private goods. Let y_i be a vector in R^M giving the production levels of the M private goods in country i. The "production functions" or "abatement functions" f_i are continuously differentiable and strictly concave, and show the trade-off between the level of abatement or quality of the atmosphere and the output of consumption. Then

$$a=\sum_{i=1}^{I} a_i,\ a_i = f_i(y_i) \text{ for each country } i=1,....I \text{ and } \frac{\partial f_i}{\partial y_{i,m}}<0 \text{ for all } i$$

An allocation is feasible if it satisfies the above constraint and also the condition that the total consumption of each private good world-wide be equal to the total production. In this framework one can prove:

Theorem 1. *(Chichilnisky Heal and Starrett) Let E^* be the level of total emissions at a Pareto efficient allocation of resources in the economy described above. Assume that regions maximise utility subject to the budget constraint given by the ability to trade emission permits:*

$$c_i = y_i - p_e[E_i + a_i]$$

[7] The formalization comes from Chichilnisky, Heal and Starrett, 1994.

Here p_e is the market price of an emission permit in terms of consumption and E_i is the quantity of emission permits allocated to region i. Assume that a regularity condition is satisfied.[8] *Then of all possible ways of allocating the total emission E* among the regions as initial endowments, only a subset of measure zero will lead to market equilibria which are Pareto efficient. Alternatively, almost every allocation of permits between regions will lead to inefficient outcomes. If the inequality*

$$(I-1)+M \leq (I-1)\times M$$

holds, then only a finite number of ways of allocating the emission rights lead to efficiency.[9]

In words, this result states what I implied above. Whether or not a market with emission permits will lead to an efficient allocation of resources depends on the allocation of emission permits between the traders. Only some, indeed a few, ways of allocating these permits will lead to efficiency.

Why does this result occur? When all goods are private, different traders typically end up with different amounts of goods at a market-clearing equilibrium, because of their different tastes and endowments. The flexibility of the market in assigning different bundles of goods to different traders is crucial for efficient solutions. But traders with different preferences should reach consumption levels at which economy-wide relative prices between any two goods are both (1) equal to the marginal rate of substitution between those goods for every trader and (2) equal to the rate of transformation between the two goods for every producer. This is an enormous task: it is a testament to the decentralised power of markets that this coincidence of values emerges at a market-clearing allocation.

When one good is public, however, there is a physical constraint: all traders, no matter how different, must consume the same quantity. This imposes an additional constraint, a restriction that does not exist in markets where all goods are private. Because of this restriction, some of the adjustments needed to reach an efficient equilibrium are no longer available in markets with public goods.

The number of instruments the market uses to reach an efficient solution—the goods' prices and the quantities consumed by all traders—is the same with private or public goods. But with a

[8] See Chichilninsky, Heal and Starrett, 1994 for details.

public good these instruments must now do more: at a market equilibrium the quantities of the public good demanded independently by each trader must be the same, no matter how different the traders are. As a result, in addition to equalising price ratios to every trader's marginal rates of substitution and transformation, an additional condition must now be met for efficiency.

The physical requirement of equal consumption by all therefore introduces a fundamental difference between efficiency with public goods and efficiency with private goods. All this must be achieved by the market in a decentralised fashion. Traders must still be able to choose freely, maximising their individual utilities, and therefore the previous condition of equating each trader's marginal rates of substitution and transformation to prices must still hold. Otherwise the market clearing allocation would not be efficient. In other words: with public goods the market must perform one more task. A Lindahl equilibrium provides extra instruments for this task, namely extra prices, by considering personalized prices for public goods. What the result above says is that redistribution of endowments can substitute for the extra prices in a Lindahl equilibrium.

Since the market with *n* private goods has precisely as many instruments as tasks, with public goods new instruments must be enlisted. The Lindahl equilibrium uses extra prices. In the present case some of the economy's characteristics can be adjusted to meet the new goals. The traders' property rights to the public good—for example their rights to emit gases into the atmosphere—are a natural instrument for this purpose, because they are in principle free and undefined until the environmental policy is considered. By treating the allocations of quotas as an instrument—by varying the distribution of property rights on the atmosphere—it is generally possible to achieve a market-clearing solution where traders choose freely to consume exactly the same amount of the public good. Market efficiency can be achieved with public goods, but only with the appropriate distribution of property rights. Again, distribution and efficiency are no longer independent.

To summarise, markets for emission permits have many advantages as mechanisms for controlling the use of atmospheric (or possibly aquatic) common property resources. Government action is a prerequisite for their effective introduction, as they require that property rights be established where typically there were previously none. Government action is also needed in allocating these newly established property rights. This allocation clearly has an impact on the

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[9] For a proof, see Chichilnisky, Heal and Starrett, 1994.

distribution of benefits arising from the use of the market: it also effects the total of the benefits as it affects the efficiency of the market outcomes.

Privatizing and Securitizing the Biosphere

I turn now to the second route by which markets can mediate between humans and the biosphere. The issue here is the following: Can we establish markets in ecosystem services? If so, we will in effect extend the scope of the market mechanism, in the process internalising many of the external effects imposed by humans on the natural environment and associated with the present institutional structure, or lack of it. This route is in the classical tradition of internalising externalities by establishing markets and property rights. The most productive approach to this question is not through general theorising but via examples and cases, so I begin with a review of four cases where this approach is, or might be, effective. After that, I place these cases in a more general context.

Watersheds

Ninety percent of New York's water comes from a watershed in the Catskill Mountains. Until recently purification process carried out by roots and microorganisms in the soil as the water percolates through, together with filtration and sedimentation occurring during this flow, were sufficient to cleanse the water to US Environmental Protection Agency standards. Recently sewage, fertilizer and pesticides in the soil reduced the efficacy of this process, to the point where New York's water no longer met EPA standards. The city was faced with a choice: restore the integrity of the Catskill ecosystems, or else build a filtration plant at a capital cost of $6-8 billion, plus running costs of the order of $300 million annually. In other words, New York had to invest in environmental conservation or in treatment facilities.

Which was more attractive? Investment in conservation in this case meant buying land in and around the watershed so that its use could be restricted, subsidizing the construction of better sewage treatment plants, and buying conservation easements in the region. The total cost of measures of this type needed to restore the watershed is expected to be in the range of $1-1.5 billion. So investing $1-1.5 billion in conservation could save an investment of $6-8 billion in treatment facilities, giving an internal rate of return of between 90% and 170%.[10] This return is an

[10] The discussion of the New York watershed case is taken from Chichilnisky and Heal, 1998.

order of magnitude higher than is normally available, particularly on relatively riskless investments. These calculations are conservative, as they consider only one watershed service, although watersheds, typically forests, often provide other important services.

In 1997 New York City floated an "environmental bond issue", and will use the proceeds to restore the functioning of the watershed ecosystems responsible for water purification. The savings produced will meet the cost of the bond issue: the savings are the avoidance of a capital investment of $6-8 billion, plus the $300 million annual running costs of the plant. The cash that would otherwise have gone to these will pay the interest on the bonds.

The market could have handled this transaction, by using the technique of securitization. This involves issuing tradable contracts, securities, entitling the owners to a fraction of the benefits from a venture. In this case, the securities would entitle their owners to a fraction of the cost savings resulting from watershed restoration: they would be “watershed securities.” In exchange for the securities, investors would contribute the capital needed for restoration. In effect they would invest in the restoration and receive in return a share of the benefits from restoration. Securitization is a technique already extensively used for attracting investors into a venture. This financial structure is already used in securitizing the savings from increased energy efficiency in buildings. Securitization of the savings involves issuing securities entitling their owners to a specified fraction of the savings. Typically these contracts are tradable, issued to the providers of capital, and can be sold by them, even before the savings are realized. This is a way of making investment in saving energy attractive to the investing public and institutions: it does not imply any transfer of ownership of the underlying asset. The US Department of Energy has a standard protocol for estimating the savings from enhanced building energy efficiency and several financial agencies are willing to accept these estimates of energy savings as collateral for loans.

In the New York watershed case, the city could have opened a "watershed savings account" into which it paid a fraction of the costs avoided by not having to build and run a filtration plant, which would pay investors for the use of their capital. The purpose of securitization is make it possible to finance projects such as New York’s watershed restoration without using the credit of the City itself, an important issue in developing countries whose metropolitan areas often do not have credit ratings comparable to New York’s.

One could take the introduction of market forces a step further. Imagine a corporation managing the restoration of New York's watershed. It has the right to sell to New York City the services of the ecosystem, the provision of water meeting EPA standards. Ownership of this right would enable it to raise capital from capital markets, to be used for meeting the costs of conserving New York's watershed. Of course some regulation would be needed: for example, the corporation would be a natural monopoly so that it would be appropriate to regulate its prices. It would also be reasonable to place some restrictions on the modifications that it could make to the natural ecosystems in the watershed area.

Analytically, what is the general point illustrated by this example? It is that water is a good for which individuals or municipalities are willing to pay. They are willing to pay for quality as well as quantity, and this in effect puts a price on the water management and purification services provided by a watershed. It generates a derived demand for watersheds. In this case there is a possible replacement for the ecosystems services provided by the watershed: this is the filtration plant. The cost of this, in the New York case $8 billion plus, puts an upper limit on what it would make sense to spend on restoring the watershed, looking at it only from the water management and purification perspective. Of course, the watershed may have many other values to society: in this case, the Catskills are a much-valued recreational area, and society has a substantial willingness-to-pay for this in addition to the watershed services. An important aspect of this story is that by improving sewage systems in the Catskills and other measures to reduce pollution there, and by buying conservation easements, the city of New York has improved the quality of life and injected a considerable amount of income into the Catskills community. It has therefore provided some financial compensation to the residents of the area to be conserved, and given them a direct financial stake in the conservation.

Ecotourism

Another powerful example comes from South Africa, in the form of the Conservation Corporation, or Conscorp, a company started as a private venture and recently floated on the London Stock Exchange.[11] This imaginative venture has capitalized on the demand for ecotourism

[11] Their web site is http://www.world-travel-net.co.uk/conscorp. For more discussion see http://economics.iucn.org. A paper on the IUCN web site by Terry Anderson, “Enviro-Capitalists: Why and How to Preserve Their Habitat” provided most of the material on Conscorp used here. The exact address is

and hunting: this demand is such that land yielding $25 per hectare annually for ranching and $70 per hectare in cropping can yield between $200 and $300 per hectare as part of a reserve managed for tourism or hunting. Conscorp contracts with landowners to incorporate their land in its reserves: it does not buy the land outright. Landowners have to maintain their land in accordance with tightly specified regulations and to stock it with specified animals. Conscorp manages the business part of the operation, bringing tourists and hunters, building facilities and providing guides and vehicles. To date they have restored several hundred thousand hectares of farmland to their original ecosystems. An interesting detail is that the presence of lions will add about 30% to the revenues from an area, so that the incentive to restock with these is great.[12] Supporting lions, at the top of the food chain, requires that most of the rest of the chain beneath them be there: what the lions eat, what the lions' food eats, and so. There is a strong economic incentive to do a thorough job of restoration. This is in fact clear from the very explicit rules used by the Conscorp, whose Articles of Association for a specific reserve state that its aims are "to promote and conserve endemic wildlife within the confines of the area ..; to establish the Reserve as a sanctuary in perpetuity for endemic wildlife and habitat so as to ensure sustainable resource utilization …; to endeavor to increase the area of the Reserve; and to maximize the long term economic and ecological value of the properties… ." Landowners even agree not to keep any domestic animals, dogs and cats included. An interesting quote from a South African writer captures some of what is happening in this movement:

> "The interesting thing as that untold hundreds of thousands of hectares and morgen that even a few years ago were scrub grazing for a mixture of game and cattle have now been entirely allocated to game. Why? Economics, as always. Game pays its own way, eats nearly anything, is more resistant to disease and predators and generally produces a higher and better use for the land … . Even the old enemies become assets to the farmer who switches from cattle to game. One friend of mine used to lose as many as thirty calves a season to leopards … . Now those same leopards are worth a cool $3000 to $4000 to sport hunters, not a bad trade-off for animals that caused a liability of well over ten grand and had to be poisoned! Tell me, is that bad for leopards?"[13]

Similar developments are occurring in Kenya. The land there is less productive and the country has less infrastructure, so that numbers are all lower. But they tell the same story in terms

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http://economics.iucn.org/96-01-14.pdf. Also of interest is Michael 't sas-Rolfes, "The Use of Auctions as an Incentive Measure for Wildlife conservation", http://economics.iucn.org/96-03-16.pdf.

[12] Personal communication, Craig Packer.

of incentives: in the Laikipia region of Kenya ecotourism can bring $5 to $30 per hectare per year, compared with less than $2 per hectare per year for traditional livestock husbandry.[14] In fact in the whole of southern Africa (Namibia, Zimbabwe, Botswana, South Africa and Mozambique) about 18% of the land area is now devoted to game management, i.e. to the management of naturally occurring wild life, largely because of the economic returns that this provides.[15]

Prospecting for Pharmaceuticals

Bioprospecting is another activity that can yield cash for conservation. Bioprospecting means seeking for leads in the development of new drugs, or new chemicals for use in agriculture, by looking at biological resources. As a matter of fact, over 60% by value of prescription drugs in the US are or were initially derived from plants and insects, so this is a reasonable place to start looking. The key point is that certain plants and animals are known to produce substances that are highly active pharmacologically. Plants that live in insect-infested areas produce substances that are poisonous to insects, and these have been used as the basis for insecticides. Some snakes produce venom that paralyses parts of the nervous system, and others produce venom that reduces blood pressure. Other insects produce anti-coagulants. All of these have been adapted for medical use. Observations of this type have led most major drug companies to pursue bioprospecting as a way of finding new pharmacologically active substances to serve as a basis for drug development. Typically they have sought these compounds in the tropics, in areas where there is extensive inter-species competition, or in other extreme areas. They have been willing to pay quite substantial sums for access to these regions, and have made deals with host countries that involve giving them a royalty on the products that might eventually be based on this prospecting. Such royalties could be large relative to the incomes of the countries concerned. Two concrete examples will illustrate the potential salience of this point. The key enzyme in the polymerase chain reaction (pcr), a reaction central to much modern genetic testing and indeed to a broader range of biotechnologies, was discovered in one of the hot springs at Yellowstone National Park. There it evolved the resistance to heat that is critical to its role in pcr. Now virtually every biotechnology laboratory uses derivatives of this enzyme, whose commercial value is immense. Merck Inc., one of the largest pharmaceutical companies in the US, has an agreement with a Costa Rican agency called

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[13] Capstick, cited by Anderson, in Chichilnisky, Heal and Starrett, 1994.
[14] Rubenstein, 1993.
[15] D. Cumming, WWF Zimbabwe, personal communication.

InBio (Institute Nacional de La Biodiversidad) for bioprospecting rights in Costa Rica. The terms of the agreement are that Merck paid InBio a fixed sum, to be used for forest conservation, in exchange for the right to receive samples collected by InBio and to use these as the basis for new product development. Should any of them prove commercially successful, Merck will pay InBio a royalty on the revenues generated. Similar agreements are in place between other US pharmaceutical companies and other regions of Central and South America. There has been some controversy about the potential value of bioprospecting to developing countries. The discovery of the enzyme for the pcr reaction, the agreement between Merck and InBio and several other drug discoveries based on plants from developing countries, led to a wave of optimism, some perhaps excessive, about the potential commercial value of in situ biodiversity in developing countries. After a reaction against this, a more balanced position is emerging, although we still lack extensive practical experience. Real data will emerge only slowly, as the development and testing of drugs is a slow process, taking at least ten years. However, recent calculations have suggested that in some the world's biodiversity hotspots, the right to bioprospect may be worth as much as $9000 per hectare, about a century of ranching income.[16] The key insight in these calculations is that prior knowledge of the nature of the ecosystems in a location can improve estimates of the probability of finding commercially interesting compounds there. In practical terms developing countries can clarify the commercial attractions of their biodiversity by research on the ecosystems of which it is a part. This is rather like a country with potential oil reserves engaging in basic geological prospecting before seeking to negotiate leases for oil development. The results may be positive or negative, but either way they will give it a better view of its prospects.

Here the economic point is recognizing the value of the knowledge that can be derived from natural systems, and then establishing intellectual property rights in that knowledge. The property rights are needed to ensure that some of the value ultimately created by that knowledge returns to the country from which it is derived.

Growing Carbon and the Kyoto Protocol

The Kyoto Protocol could provide an interesting example of how markets might provide powerful incentives for environmental conservation. The final version of the Protocol may contain

[16] See Rausser and Small, 1998. These figures apply only to selected locations recognized as rich in biodiversity and should not be taken as typical of tropical regions.

provisions for carbon sequestration credits: under these provisions, countries that remove carbon from the atmosphere, for example by growing trees, will receive credits for this in the form of tradable greenhouse gas emission permits. No one knows what exactly the value of these permits will be. Preliminary economic calculations[17] suggest that their market value could be in the range $15 to $100 per ton of carbon or equivalent, but until markets for carbon emission permits are active we will not be sure of this. What would this mean for the economics of conserving tropical forests? Again, we don't know for sure, but we can do some rough calculations. Growing moist tropical forests remove carbon from the air at a rate in the range of 5 to 15 tons per hectare per year, possibly more.[18] Taking these two ranges of numbers together, we see that growing forests could be remunerated by carbon sequestration credits at a rate of $75 to $1500 per hectare per year. This is a lot of money: ranches in Costa Rica, for example, make profits of at most $100 to $125 per hectare per year. Reforesting has a one-off cost of planting the seedlings, which can be as high as $900 per hectare.[19] Even with this initial cost, it seems possible that if the world as a whole pays for just one of the many services of tropical forests, then this could change radically the economics of forest conservation. On a very small scale, some of this is already happening through the schemes for joint implementation encouraged by the Global Environment Facility and the World Bank.

Analytically this example demonstrates the following point. The sequestration of carbon by forests is a global public good. By stabilizing the climate it benefits all of humankind. Typically it is difficult for the providers of such a service to appropriate all or even a significant part of the benefits, so that it is under-provided, as we noted above. A combination of a tradable permit system for greenhouse gas emissions plus a regime of giving permits for sequestration may allow ecosystems that provide sequestration services to capture the full economic value of what they provide.[20]

Privatization and Securitization: Conclusions

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[17] The range of $10 to $50 emerges from simulations conducted by the Program on Information and Resources at Columbia University using a modified version of the OECD's GREEN computer model of the global economy. W.D. Nordhaus of Yale has reported estaimates as high as $100 (personal communication).
[18] Personal communication, Steve Pacala, Ecology Department, Princeton.
[19] Personal communication, Daniel Botkin.
[20] The assertion that markets give appropriate incentives for providing public goods is a surprising one to most economists in view of the free rider problem. For a detailed analysis, see Chichilnisky and Heal, 1998.

These examples – carbon sequestration and the Kyoto protocol, the New York watershed, the Conscorp and bioprospecting – make two points. One is that, with the right institutional structures and property rights in place, the market can be used to realize some of the value inherent in certain natural assets. The second is that, if this is done, then incentives for conservation can be generated. If the market will yield a higher return through conservation than through any other use, then entrepreneurs will find a way to conserve. Of course, I have cited particular examples: they do not imply that all valuable natural capital can be conserved this way. What they do suggest is that we should look more into the potential of this approach. Preliminary estimates suggest that up to ten percent of the land area of the US, and a comparable or greater area worldwide, could be economically conserved on the grounds of watershed protection.[21] I am not aware of comparable studies for ecotourism, but this has certainly become a major industry in several regions of the world, including Central America and East and Southern Africa. As noted above, in southern Africa approaching 20% of the land area is now conserved because of the economic incentives provided by ecotourism. Some countries in these regions are now earning about one third of their foreign exchange from ecotourism.

What is the potential for application of privatization or securitization to a broader range of ecosystems? Daily (1997) identifies the following social and economic functions of ecosystem services: purification of air and water: mitigation of floods and droughts: detoxification and decomposition of wastes: generation and preservation of soils: control of the vast majority of potential agricultural pests: pollination of crops and natural vegetation: dispersal of seeds: cycling of nutrients: maintenance of biodiversity: protection of coastal shores from erosion: protection from harmful ultraviolet rays: partial stabilization of the climate, and provision of aesthetic beauty and intellectual stimulation that lift the human spirit.

Which of these are amenable to the approach that we have indicated? One clear prerequisite is that the ecosystem to be conserved must provide goods or services to which a commercial value can be attached. Watersheds satisfy this criterion: drinkable water is becoming increasingly scarce, and indeed the availability of such water is one of the main constraints on health improvements in many poorer countries.

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[21] These numbers come from Reid, 1998. In this paper, Reid begins to explore the scope for generalizing the New York case to other regions.

Commercial value of an ecosystem service is necessary but not sufficient for privatization: some of that value has to be appropriable by the producer. A critical issue in deciding whether ecosystem services can be privatized, is the extent to which they are public goods. Pure public goods are challenging to privatize. It is hard, though often not impossible, to exclude from benefiting from their provision those who do not contribute to their costs, so that their providers cannot appropriate all of their returns. Water quality is a public good, in the sense that if it is improved for one user of a watershed, then it is improved for all. But the consumption of water itself is excludable, so the watershed case involves bundling a public with a private good. Knowledge, an intermediate category and one of the services of biodiversity, has to be commercialized with care, as shown by the need to protect it with patents, copyrights and other supports of intellectual property rights. Many of the examples that I have cited above – watersheds, carbon sequestration, and ecotourism – have the characteristics of what have been termed club goods, goods which can be provided as public goods to a select group of people who agree to finance their provision. This is the kind of arrangement often used to finance the provision of facilities such as tennis or golf clubs, and indeed represents a particular way of privatizing the provision of certain public goods.[22]

A final observation on the privatization approach: the different ways of obtaining a return described in the examples above are not mutually exclusive. A forest could obtain returns from carbon sequestration, bioprospecting, managing a watershed and ecotourism. In fact, the region of the Mata Atlantica (Brazilian coastal rainforest) inland from Rio de Janeiro is in a position to do exactly this. It manages the watershed for Rio in much the way that the Catskills region does for New York. It also manages the streamflow of the river Rio Paraibo do Sul, which provides most of the hydropower for Rio. These two services make it truly a major utility for Rio, with great economic value. Additionally it supports a wide range of endemic species, sequesters carbon and acts as a magnet for tourists. Currently the region obtains a financial return only on one of these activities, ecotourism.

Conclusions

[22] On clubs, see Cornes and Todd, 1996.

There are two routes via which markets can contribute to environmental conservation. One is the route marked out by the 1990 Clean Air Act in the United States, and followed by the Kyoto Protocol. The formula here is to note that many environmental goods and bads are public goods or bads, and then to use permit markets to control production of these. The public nature of the goods coupled with the use of a market introduces some novel features into the analysis, concerning the links between efficiency and distribution. The alternative route is simultaneously more traditional and also more novel. It is more traditional in that conceptually from an economic perspective it breaks no new ground: it is more innovative in that it is only very recently that we have any concrete cases of this method being applied successfully. This alternative route involves establishing markets in the services provided to human societies by natural ecosystems, and thereby bringing many externalities within the domain of the market.

In general neither of these approaches will emerge naturally. The former clearly requires a particular legal infrastructure and in particular the establishment of transferable property rights in a good that was previously common property. The latter approach is perhaps more capable of spontaneous emergence, as illustrated by the case of the Conservation Corporation and the activities of various water companies in putting pressure on government for control over watershed areas. But even this approach will clearly benefit from government actions to establish a favourable legal regime. In the case of the Conservation Corporation, the existence of private property rights in fugacious animals was important in ensuring the full benefits from a growing market for ecotourism and hunting.

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